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PROPOSED MODIFICATION OF THE JET FLOW FROM THE BRL 1.68-METER SHOCK TUBE

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APPLIED RESEARCH ASSOCIATES, INC.

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13. ABSTRACT *(Maximum 200 words)*

The jet from the open end of the BRL 1.68-meter shock tube can produce high drag loading on a target with relatively little accompanying overpressure. This environment has characteristics resembling that of the non-ideal blast from a nuclear explosion. It has been proposed that the BRL 1.68-meter shock tube be developed as a non-ideal blast simulator. The flow from the tube has been used to overturn an item of military equipment. The jet from the tube is narrow. In this study, a small model of the tube with a steady-flow jet was used to examine the possibility of broadening and flattening the jet velocity profile. Several fixtures were built and attached to the end of the tube. These divided the flow into several jets directed to produce the desired jet modifications at ten diameters from the end. A six-jet and a ten-jet fixture produced acceptable modifications. A plan for development and testing for the BRL 1.68-meter tube was developed.

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I. INTRODUCTION

A nuclear explosion at a typical height used for attacking ground targets will produce a blast wave over most surfaces that is non-ideal. The thermal radiation from the explosion may produce a heated gas layer over the ground surface. The incident blast wave travels faster in the heated layer and a precursor wave develops that extends in front of the main blast wave. The temperature of the heated layer decreases with distance and eventually the blast wave reverts to a near-ideal form.

The non-ideal blast wave may have a slowly rising pressure front instead of a discontinuous shock front, so that high reflected pressures are not produced on targets. However, the corresponding gas flow may be enhanced, so that drag loads produced on a target may be several times larger than those that would occur in the absence of a thermal layer. Such large increases in drag loading extend the range for damage to targets such as tanks, armored personnel carriers, trucks, truck-shelter systems and other material. The increases in damage radii can be at least 50 percent.

At this time the successful simulation of non-ideal blast loading on full-scale vehicles has not been accomplished. The largest scale experiment to date was on Operation MISTY PICTURE. A bag 122 meters wide and 213 meters long and 0.61 meters high containing a gas with a high sound velocity was used with a 4800 ton high-explosive charge to generate non-ideal loading on models. Clearly such a simulation technique is very costly and not suitable for routine testing of military equipment and components.

Mr. Charles N. Kingery of the Ballistic Research Laboratory (BRL) has observed that the wave exiting from the open end of a shock tube can produce a blast environment with some of the characteristics of the non-ideal blast from a nuclear explosion. He has proposed developing the BRL 1.68 meter shock tube as a non-ideal blast simulator. This tube has a driver chamber that is 107 meters long and a driven chamber that is 110 meters long, so that long-duration waves can be produced. Following is a quote from his BRL briefing paper:[1]

" Currently the need to evaluate vehicle overturn protection devices, such as outriggers, as well as the need to study "non-ideal" blast loading of targets, has stimulated interest in using the area outside the open end of the BRL 1.68 meter shock tube as a test bed. The cold jet exiting from the tube has enormous impulse that should be adequate for evaluating candidate outriggers. Blast parameters in the jet closely resemble non-ideal blast parameters: i. e., relatively slow pressure rise times, low overpressure, high stagnation pressure, and high turbulence. Pressure-versus-time wave shapes look very much like non-ideal nuclear blast wave shapes."

A facility capable of producing high drag loading with low overpressure would be of value for testing equipment designed to survive near-ideal blast waves. Currently military equipment is tested on large-scale HE events such as MISTY PICTURE and MISERS GOLD. Because of the low equivalent nuclear explosion yield and the corresponding short drag loading period, the overturning threshold for some targets cannot be investigated. They would have to be placed at unrealistically high overpressure levels. Testing in the jet outside the BRL shock tube would subject the target to drag loading high enough to cause overturning without overkill from reflected shock overpressures.

As noted by Kingery, such a facility would be very useful for evaluating outrigger designs intended to prevent a target from overturning. On MISERS GOLD the prototype outriggers for a system failed catastrophically. Prior to future tests on HE events, systems with outriggers can be tested outside the BRL shock tube before taking them to the field.

The BRL 1.68-meter shock tube has been used to load and overturn a mobile electric power generator on a trailer placed 15 meters from the open end of the tube.[2] These tests took place in June, 1990.

Kingery and Gion made measurements of the jet flow from a small shock tube in a configuration that is an approximate model of the BRL 1.68-meter shock tube[3]. The small shock tube has an inside diameter of 25.4 millimeters, a driver section 1.5 meters long, and a driven section 1.33 meters long. The ratio of driver length to driven length is 1.13. The wall thickness of the tube is 12.7 millimeters. The height of the tube axis above the ground plane was one diameter

in their experiments.

The BRL 1.68-meter diameter shock tube has a driver length of 106.7 meters and a driven length of 109.7 meters. The ratio of driver length to driven length is 0.97. The height of the shock tube axis above the ground plane is 1.14 diameters. The small shock tube has a driver to driven length that is 16 percent larger than that of the 1.68 meter tube. The height in diameters of the shock tube axis above the ground plane of the small shock tube is 12.3 percent less than that of the large tube. Thus the configurations are not radically different. However, except for the wall thickness, the small tube dimensions are less by a factor of 66.

Another difference is that the data from the small shock tube were obtained for shock overpressures where the flow behind the shock is supersonic. The 1.68-meter tube is normally not fired above 140 kPa (20 psi) where the flow is subsonic with a Mach number of 0.58.

Because of the differences listed above, it is not known how well the data from the small tube apply to the large tube. Nevertheless, they are used below to obtain an estimate of the profile of the stagnation pressure impulse for the 1.68 meter tube.

Kingery and Gion made measurements of stagnation pressure impulse on the small shock tube axis and at 1.5 and 3.0 diameters off-axis. Figure 1 shows the profile of the jet impulse at a distance of ten diameters from the open end at the tube. (Ten diameters is a convenient distance for testing outside the 1.68-meter tube.) The function drawn through the data is shown in the figure.

The jet is rather narrow. Assuming that the profile in Figure 1 applies for the 1.68-meter tube, Figure 2 shows it superimposed over the profile of the mobile electric power generator/trailer as it was exposed about ten diameters from the end of the tube. Distances along the abscissa are in tube diameters. Also shown is the jet profile superimposed over profiles of a 2-1/2 ton truck and an armored personnel carrier. It is evident that stagnation pressure impulse loading will not be uniform across any of the three targets.

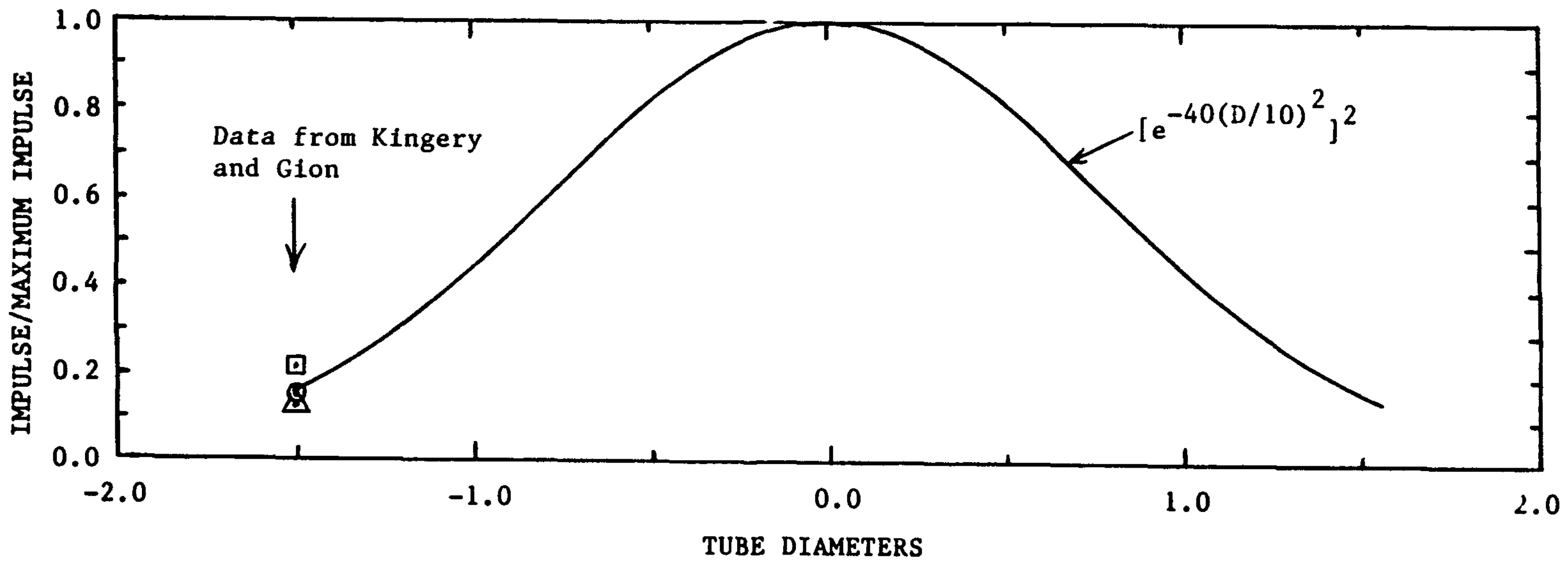

Figure 1. Estimated normalized stagnation pressure impulse profile at a distance of ten diameters using data from Kingery and Gion.

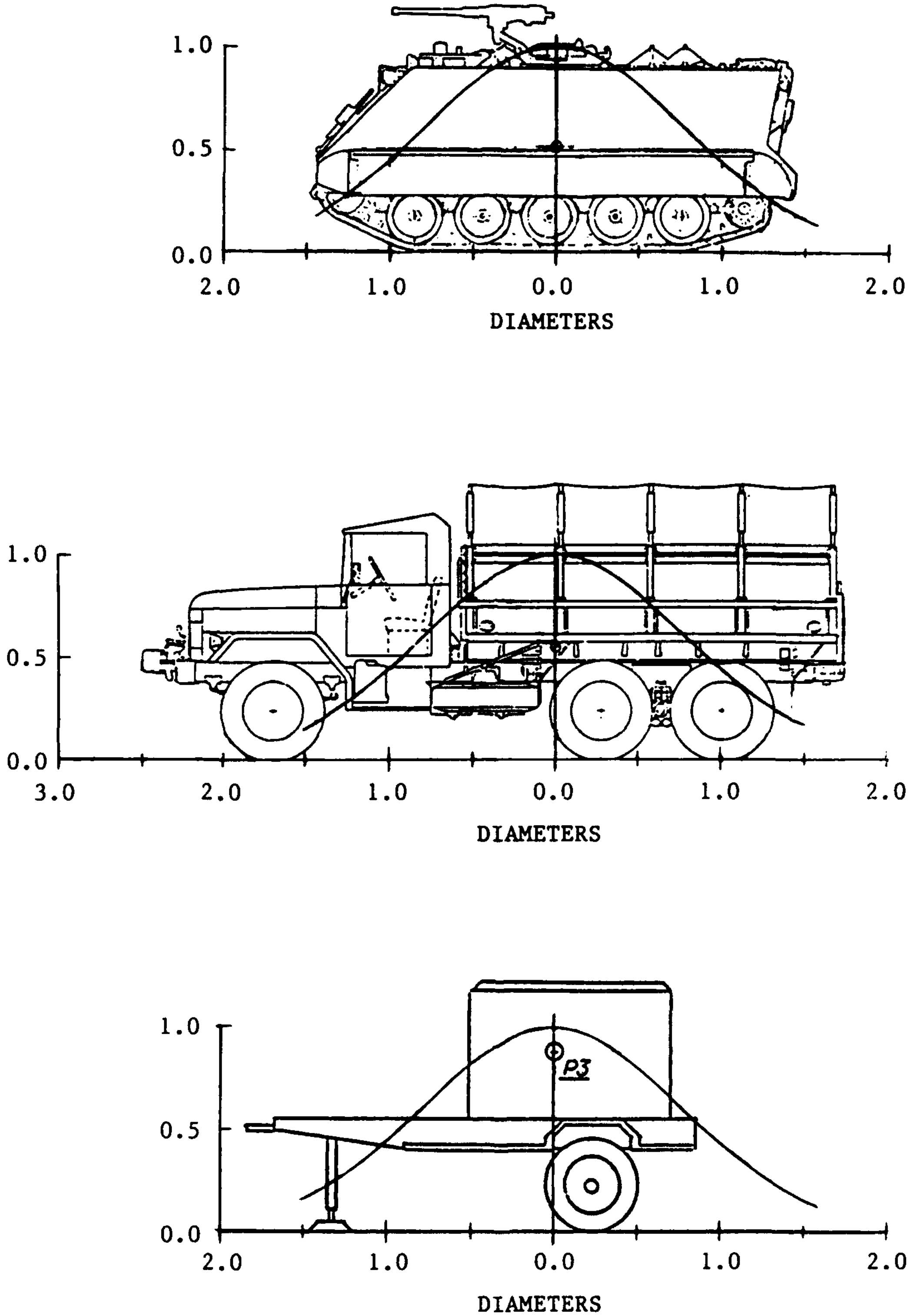

Figure 2. The estimated stagnation pressure impulse profile for the 1.68-meter shock tube superimposed over an armored personnel carrier, a 2-1/2 ton truck, and a mobile electric power generator on a trailer at ten diameters distance.

For a more realistic simulation of blast wave loading, the jet stagnation pressure impulse profile needs to be broadened and flattened. This report describes a limited exploration of the possibility of so modifying the jet from a cylindrical tube by adding a fixture on the end.

II. OBJECTIVES

The primary objective was to investigate the feasibility of broadening and flattening the jet stagnation pressure impulse profile from a tube in a configuration similar to that of the BRL 1.68 meter shock tube.

A secondary objective was to develop a program for modifying the BRL 1.68 meter shock tube for use as a drag loading test facility.

III. APPROACH

For this exploratory study a low-velocity steady-flow jet was employed. If the profile of such a jet could be broadened and flattened as desired by addition of a fixture at the open end of the cylindrical tube, then proceeding to further studies to develop a fixture for the 1.68-meter shock tube would seem to be justified.

A. Jet Source.

The jet source was an electric power blower such as is used for blowing leaves around a lawn. It was a Paramount Model PB150, made by Allegretti & Company, 9200 Mason Avenue, Chatsworth, California 91311. It had a one horsepower motor, and was supposed to generate air speeds up to 56 meters per second, which corresponds to the flow velocity behind a 3.7 psi shock wave. The air intake was adjustable for flow control. For this experiment it was adjusted for the maximum opening.

The shock tube was modeled by a 0.940 meter (37 inch) long cardboard mailing tube with a 76.2 millimeter (3 inch) inside diameter, and a 2.38 millimeter (3/32 inch) wall thickness. The blower tube was inserted into the

mailing tube and taped in place. The flow had a run of about twelve diameters in the mailing tube before exiting.

One concept for the fixture to modify the jet used triangular tubes. A triangular tube was made of the same length and same cross-sectional area as the mailing tube so that the free-air jets from a circular cylinder and a triangular cylinder could be compared.

B. Instrumentation.

The anemometer used was the Alnor Model 8530D-I with a pitot tube made by Alnor Instrument Company, 7555 North Linder Avenue, Skokie, IL 60077. Figure 3 shows the instrument. The pitot tube is 7.9 millimeters in diameter and the nose port is 2.8 millimeters in diameter. The side-on inlet ports consist of eight holes about 0.8 millimeters in diameter spaced evenly around the circumference. They are located 67 millimeters from the nose.

The anemometer has a range from 0 to 5 kPa in pressure and 3.1 to 91 meters per second. It provides a digital display. Output can be selected to be pressure or velocity. To minimize fluctuations in readings in the turbulent jet, velocity was selected. The anemometer computed the velocity from the pressure assuming no density change in the air.

C. Jet-Modification Fixtures.

The jet can be broadened by simply using a flared end. To flatten the profile, however, it seemed necessary to break the main jet into a number of smaller jets and direct them so that entrained air would slow the flow more or less uniformly across the broadened jet.

Figures 4 and 5 show a fixture designed to be placed against the end of the cylindrical tube. It consists of six tubes of triangular cross-section containing six cylindrical tubes each. At the exit end a balsa wood spacer separates the triangular tubes. The spacing shown was the most successful.

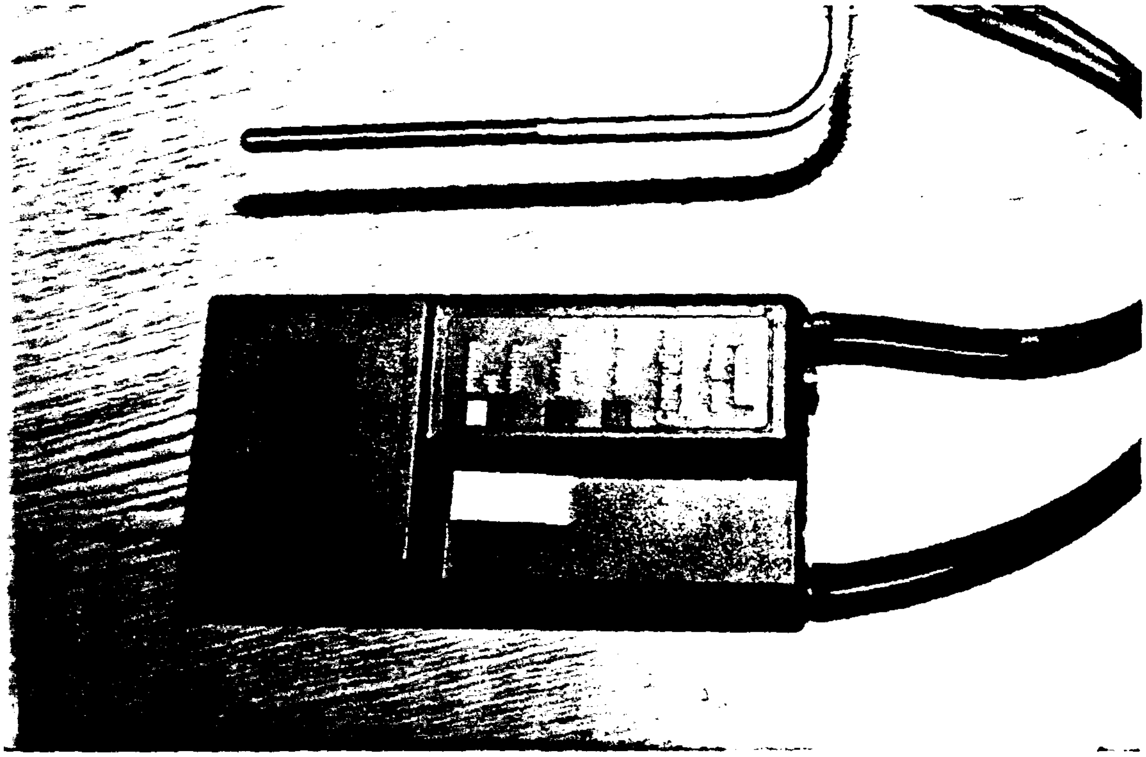

Figure 3. The Alnor Model 8530D-I anemometer and pitot-static probe.

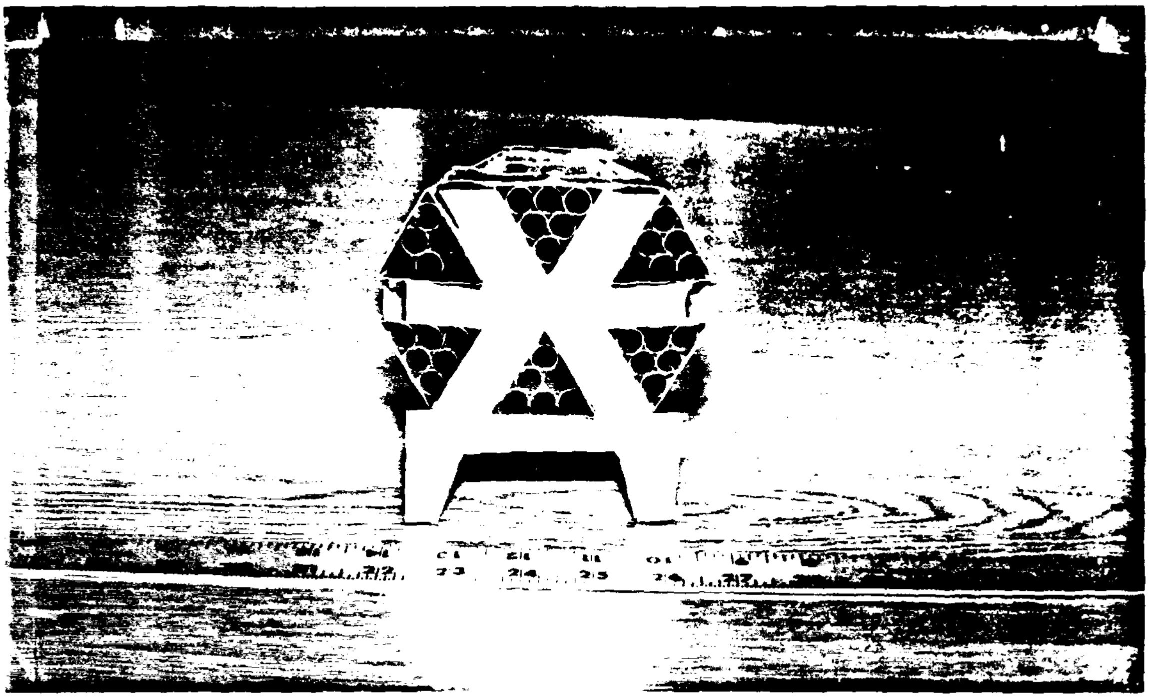

Figure 4. The exit end of the six-jet fixture in the best jet-spreading configuration.

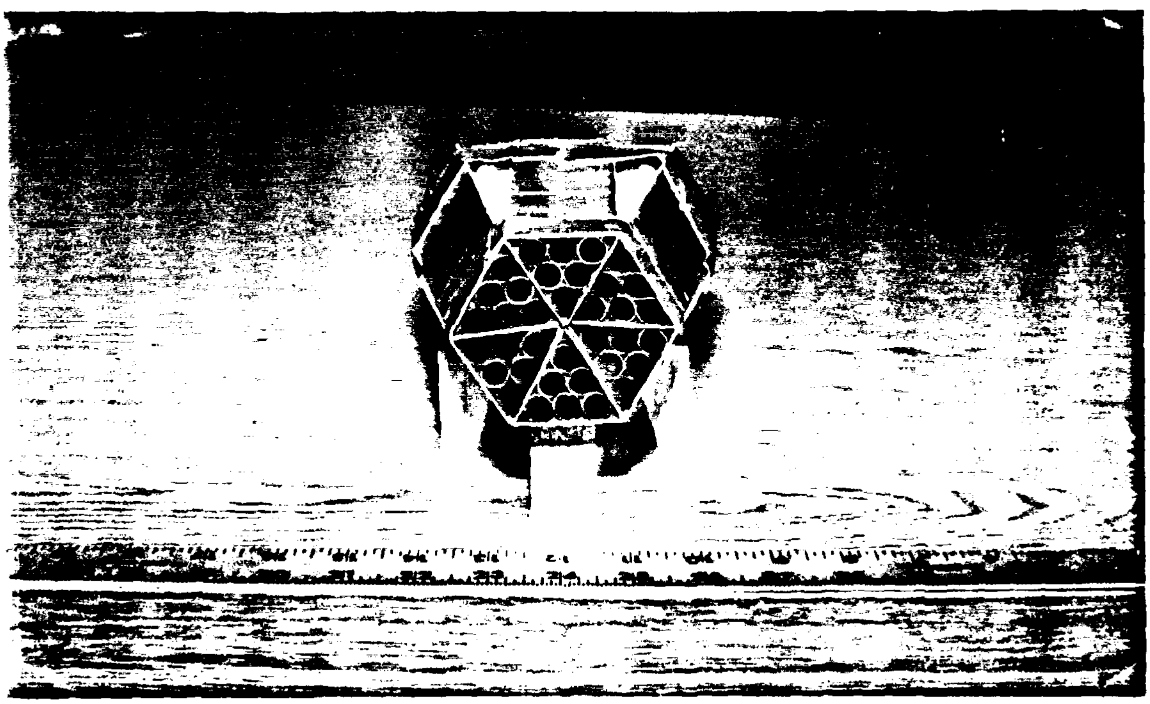

Figure 5. The entrance end of the six-jet fixture that was placed against the end of the cylindrical tube.

The tubes were brass and the plates were aluminum. The brass tubes were 102 millimeters long (4 inches) and 10.2 millimeters (0.4 inches) in diameter so that the tubes were 10 diameters (4 inches) long. It was assumed that after traveling at least 10 diameters the exiting flow direction would be parallel to the axis of the jet tube.

Figure 6 shows a 10-jet configuration. It was constructed of balsa wood. The cross-sections of each of the 10 large tubes were selected so that all would have equal areas. The small tubes are plastic soda straws placed in the larger tubes to straighten the flow. The configuration shown is the best found for the fixture. The upper two end jets are displaced inward about six millimeters.

Several other fixtures were built and tested, including a 14-jet configuration. For that configuration, the velocities measured in the spread jet were too low for adequate definition of the jet profile. The two fixtures shown in Figures 4, 5, and 6 are the best found in this study.

IV. OPERATIONS

Initially the blower and attached cylindrical tube were mounted for measurement of the jet in free air. A large level conference table served as a base. The tube extended 0.533 meters (21 inches) beyond a supporting box, and its axis was level and at a height of 0.445 meters (17.5 inches) above the top of the table. Measurements were made in the horizontal plane at axis height and in the vertical plane 10 diameters from the tube end.

After measurements with the cylindrical tube were concluded, the triangular tube was installed, and the measurements repeated.

For modeling the shock tube configuration, the blower with cylindrical tube attached was mounted on the conference table so that the axis of the tube was parallel to the conference table surface and 1.14 diameters above it. Figure 7 shows the blower and attached tube. A meter rule is shown in the figure also.

Figures 8 and 9 show the instrumentation layout. A rule was taped to the conference table with its edge toward the jet source ten diameters (30 inches)

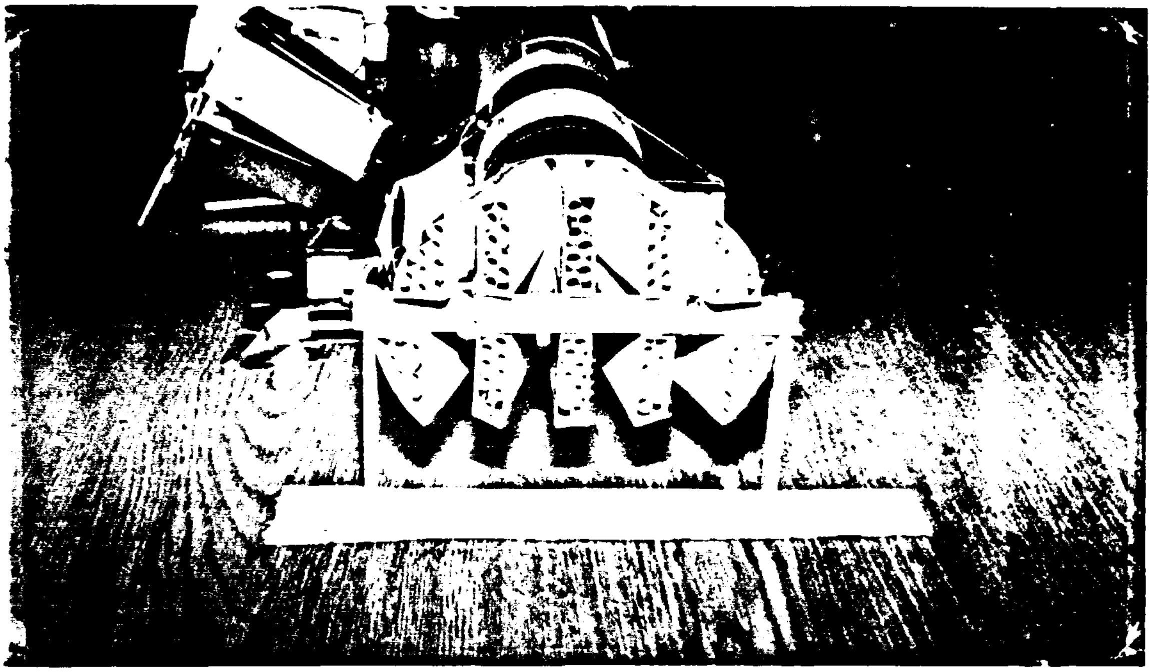

Figure 6. The ten-jet fixture in the best configuration found.

Figure 7. The cylindrical tube and attached blower mounted to model the 1.68-meter shock tube.

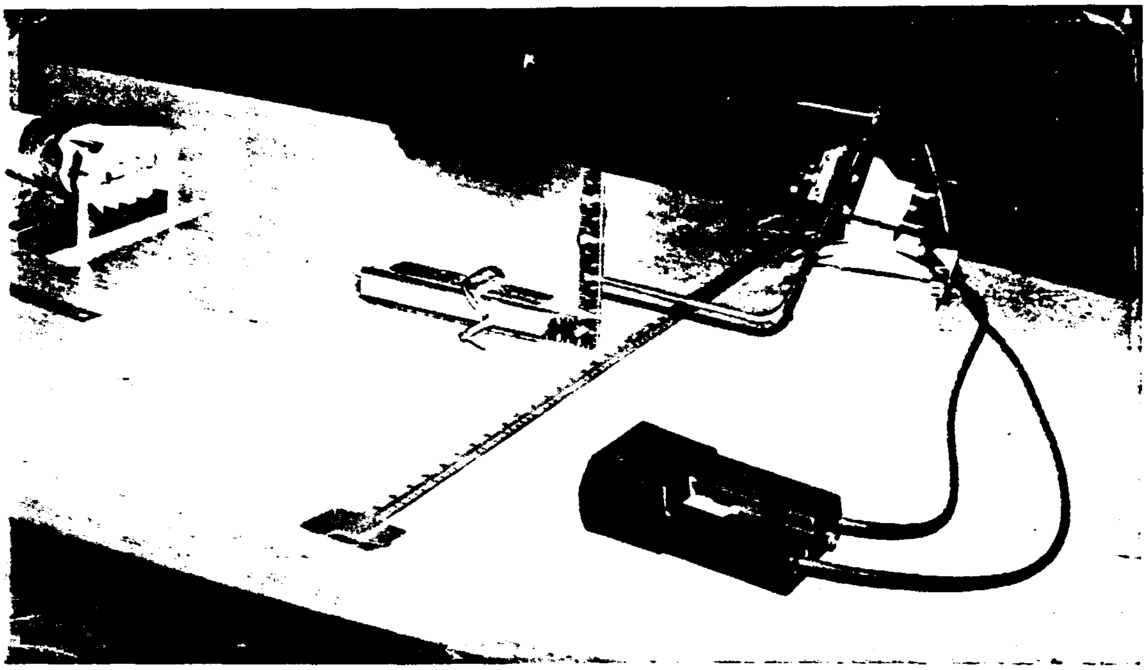

Figure 8. Instrumentation layout showing measurement of height of the pitot-static probe.

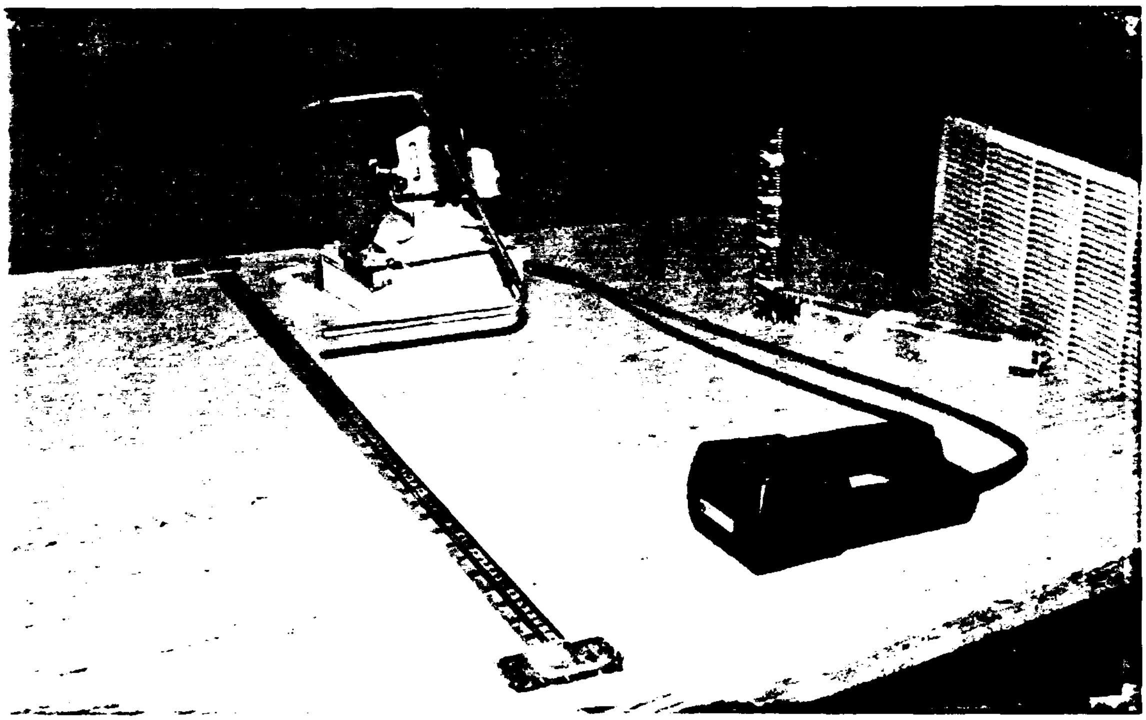

Figure 9. The pitot-static probe in position for a measurement.

from the end of the cylindrical tube and perpendicular to the tube axis. The pitot tube was held by an adjustable vise mounted on a movable wooden block. It was adjusted to be pointing at the fixture with the nose at a selected height for a measurement.

Measurements were made in horizontal planes at 0.5, 1.0, 1.5, and 2.0 times the height of the tube axis. Figure 8 shows a square with triangular pieces of tape marking the selected heights of measurement. Figure 9 shows the pitot tube set for a measurement. Figure 10 shows the view over the 10-jet fixture with the pitot tube set for an on-axis measurement.

Measurements were made at 25.4 millimeter increments starting where a signal was detected at one end of the rule and moving across the jet until no signal was detected. Then the height of the pitot tube was changed and the process repeated. If the profiles were not satisfactory, adjustments were made in the pointing directions of the jet tubes in the fixture, and the measurements repeated. This process was continued until what seemed to be the best configuration was found for the two most promising fixtures.

V. RESULTS

A. Free-Air Jets.

The velocity profiles of the free-air jets from the tubes of circular and triangular cross-sections are shown in Figure 11. The function exp $(-a\,(D/C)^2)$ was fitted to the data. This function is that for the velocity profile of a submerged axisymmetric turbulent jet.[4] D is the off-axis distance in the plane perpendicular to the axis at a range of C diameters, and a is a coefficient.

The width of the jet for the triangular cross-section tube is about twelve percent less than that for the cylindrical tube. This difference is small, and offers no basis for avoiding use of jet tubes of triangular cross-section if their use provides a convenient division of the exit area of the shock tube opening.

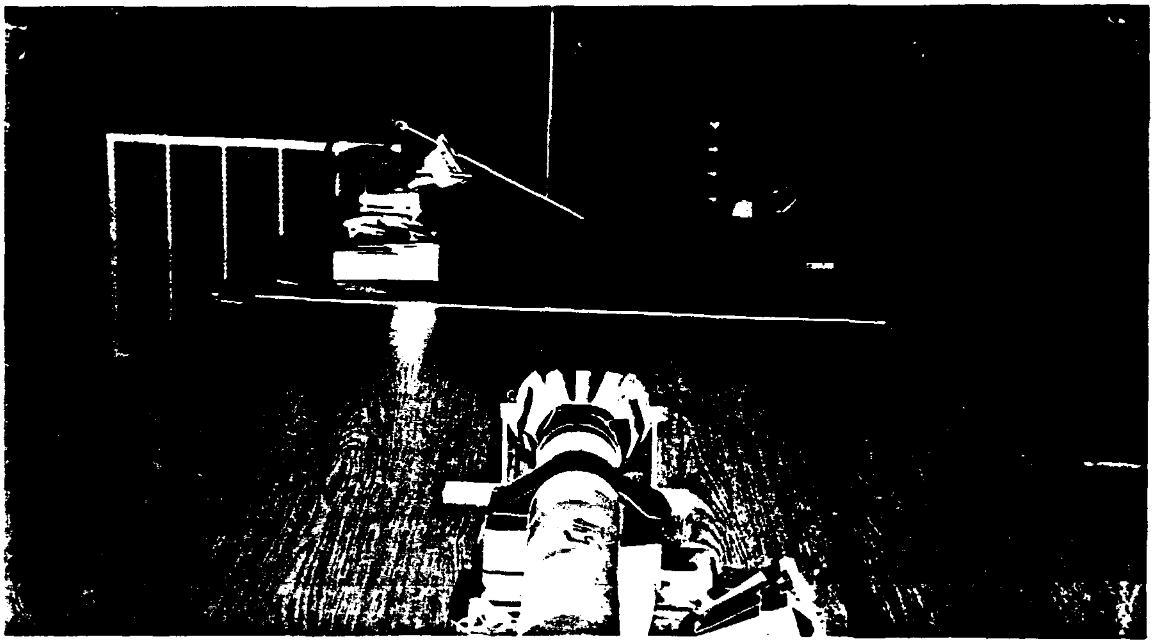

Figure 10. View over the ten-jet fixture with the probe set on-axis.

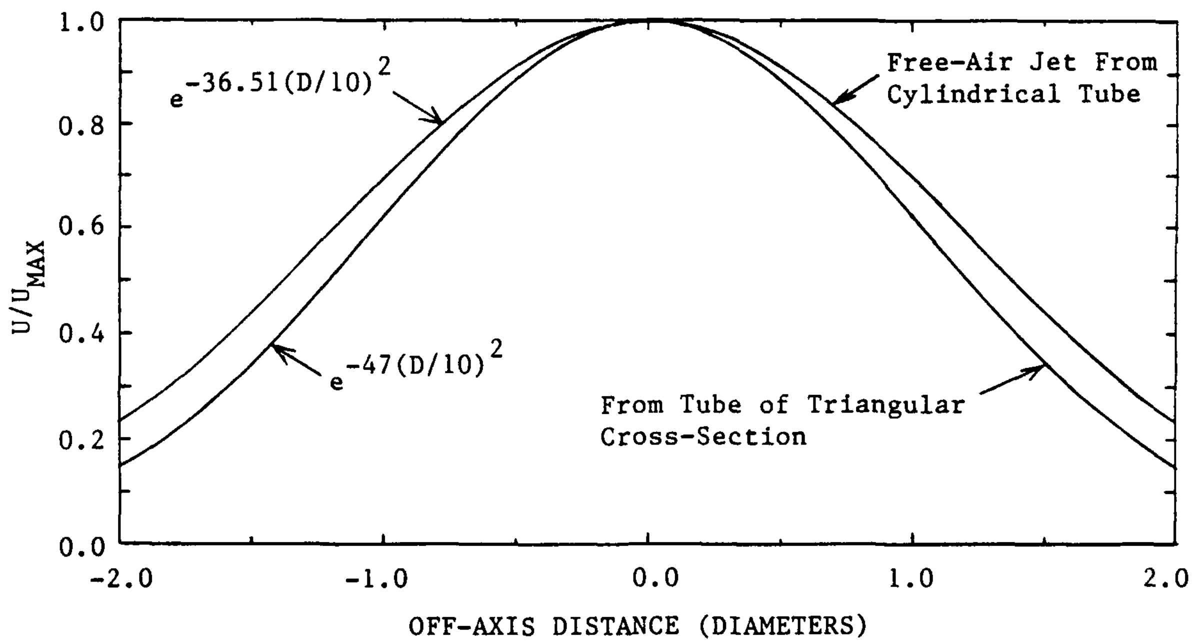

Figure 11. Normalized velocity profiles of free-air jets from tubes of circular and triangular cross-sections.

B. Jet from Cylindrical Tube over a Ground Plane.

Figure 12 shows the velocity profiles for an open-ended cylindrical tube with its axis 1.14 diameters above the surface of the conference table. This configuration models that of the 1.68-meter shock tube. The exit velocity was 29.5 meters per second. The maximum velocity occurred for the centerline height, with that at one-half the centerline height only slightly less.

Figure 13 shows the fit of the turbulent-jet velocity profile function to the measurements at the height of the centerline. In Figure 14 this profile is compared to those from the free-air jets. The effect of placing the jet near a ground plane has been to reduce its width from 2.75 diameters to 1.8 diameters. Width is defined as twice the distance off-axis at which the velocity is one-half the value on the axis.

The air density for the steady-flow jet remains constant, so the normalized velocity profile can be converted to one for dynamic pressure by squaring the ordinates, since dynamic pressure is defined as one-half the density times the square of the velocity. Since the velocity does not change with time, the profile for dynamic pressure also should apply for dynamic pressure impulse. Figure 15 shows this profile compared to the impulse profile derived from the small shock tube measurements of Kingery and Gion shown in Figure 1. Its width is 29 percent less than that for the small shock tube profile. If it applies for the 1.68-meter shock tube, then the loading on targets is even more non-uniform than that shown in Figure 2.

C. Jet from the Six-Jet Configuration.

Figure 16 shows the velocity measurements made at three heights for the six-jet configuration shown in Figures 4 and 5. The dark circles show the aim points of the centers of the six jets in the vertical plane perpendicular to the tube axis ten diameters from the end of the cylindrical tube. The aim points were about 2.5 diameters apart horizontally and slightly more than two vertically. The zero readings for velocity at the outer aim points were unexpected. The profiles are reasonably flat over a span of about 2.7 diameters for the two lowest heights. This is wide enough to cover the generator/trailer

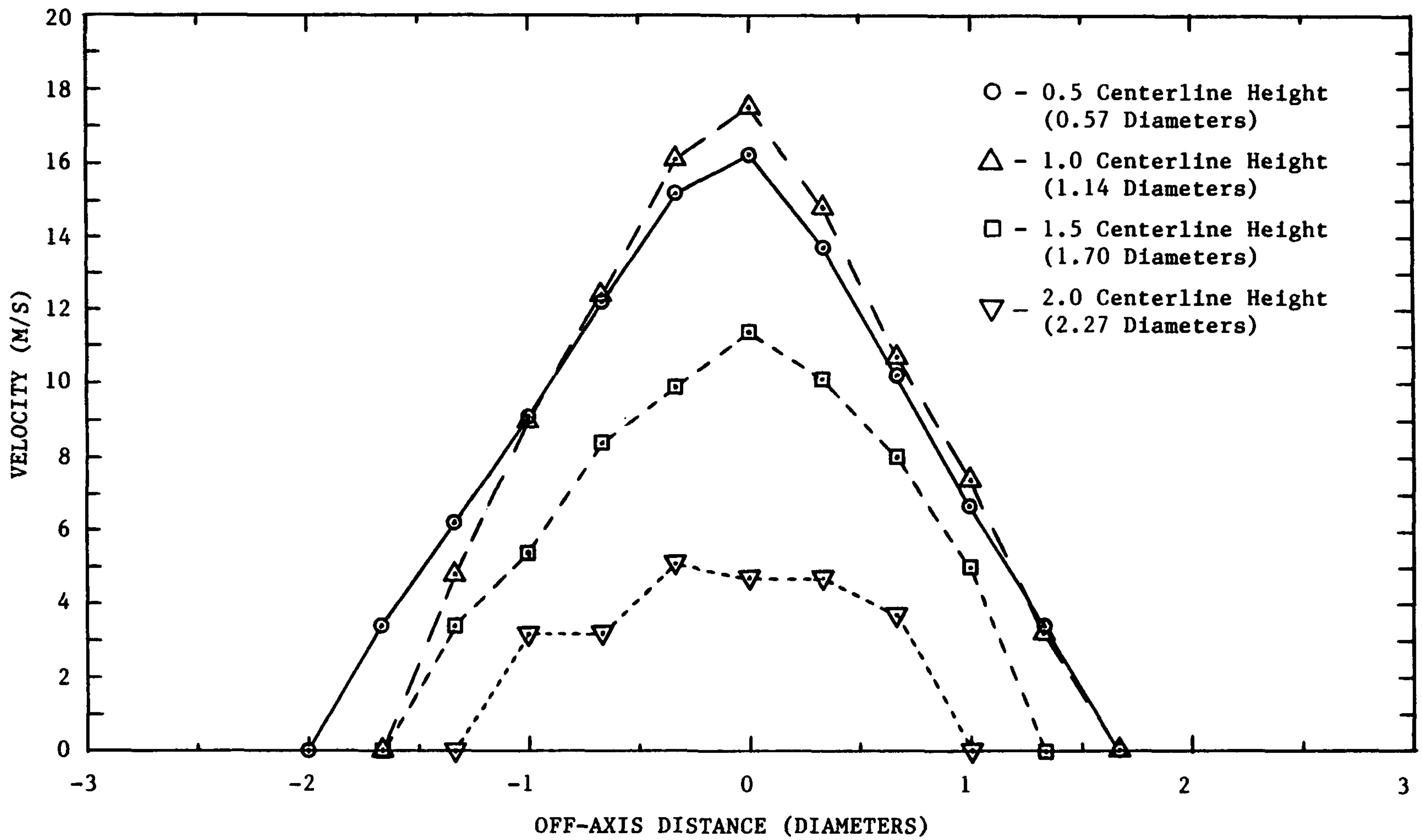

Figure 12. Velocity profiles at different heights above the surface from the open-ended cylindrical tube.

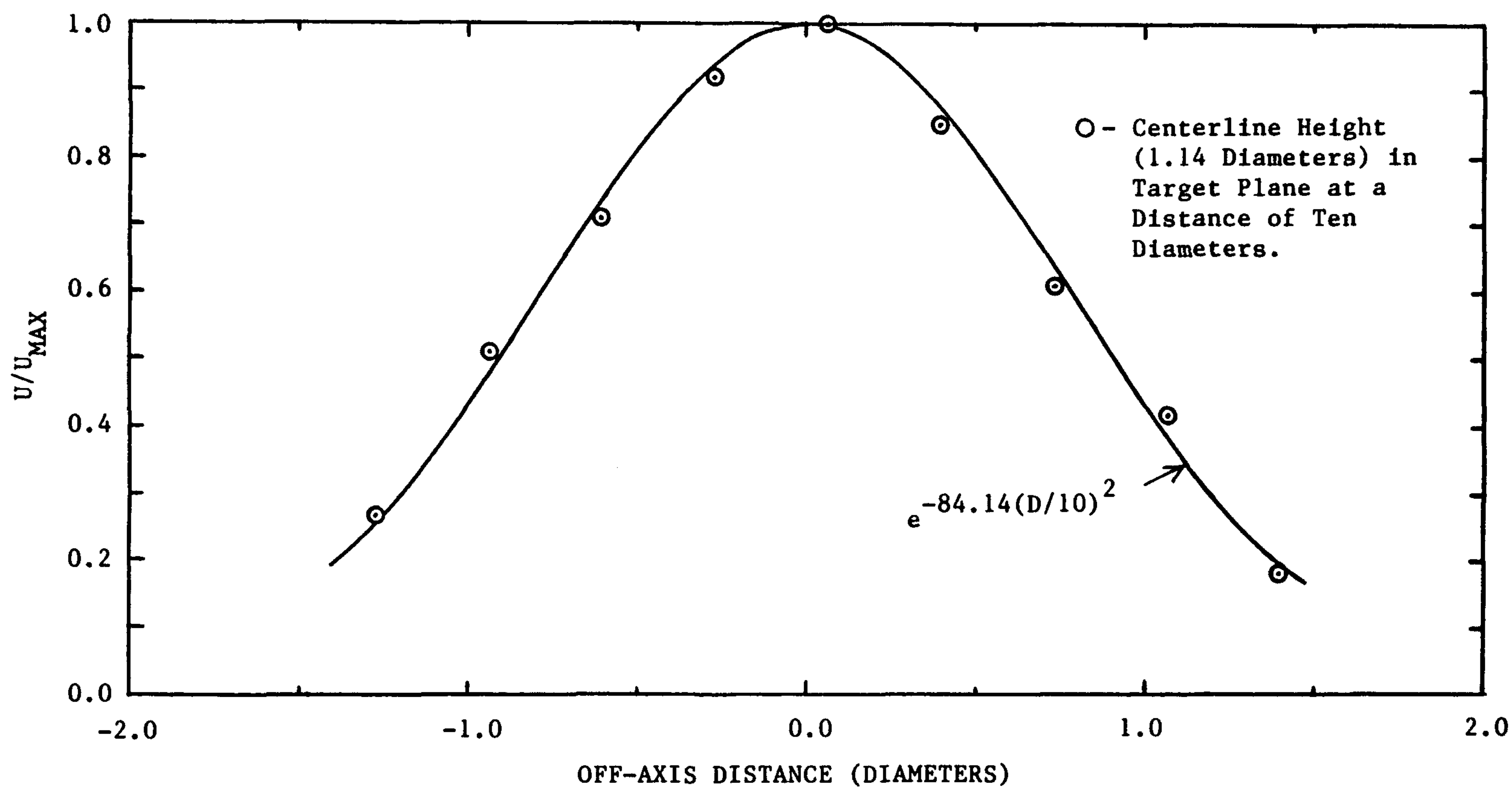

Figure 13. The jet velocity profile at the height of the axis of the tube.

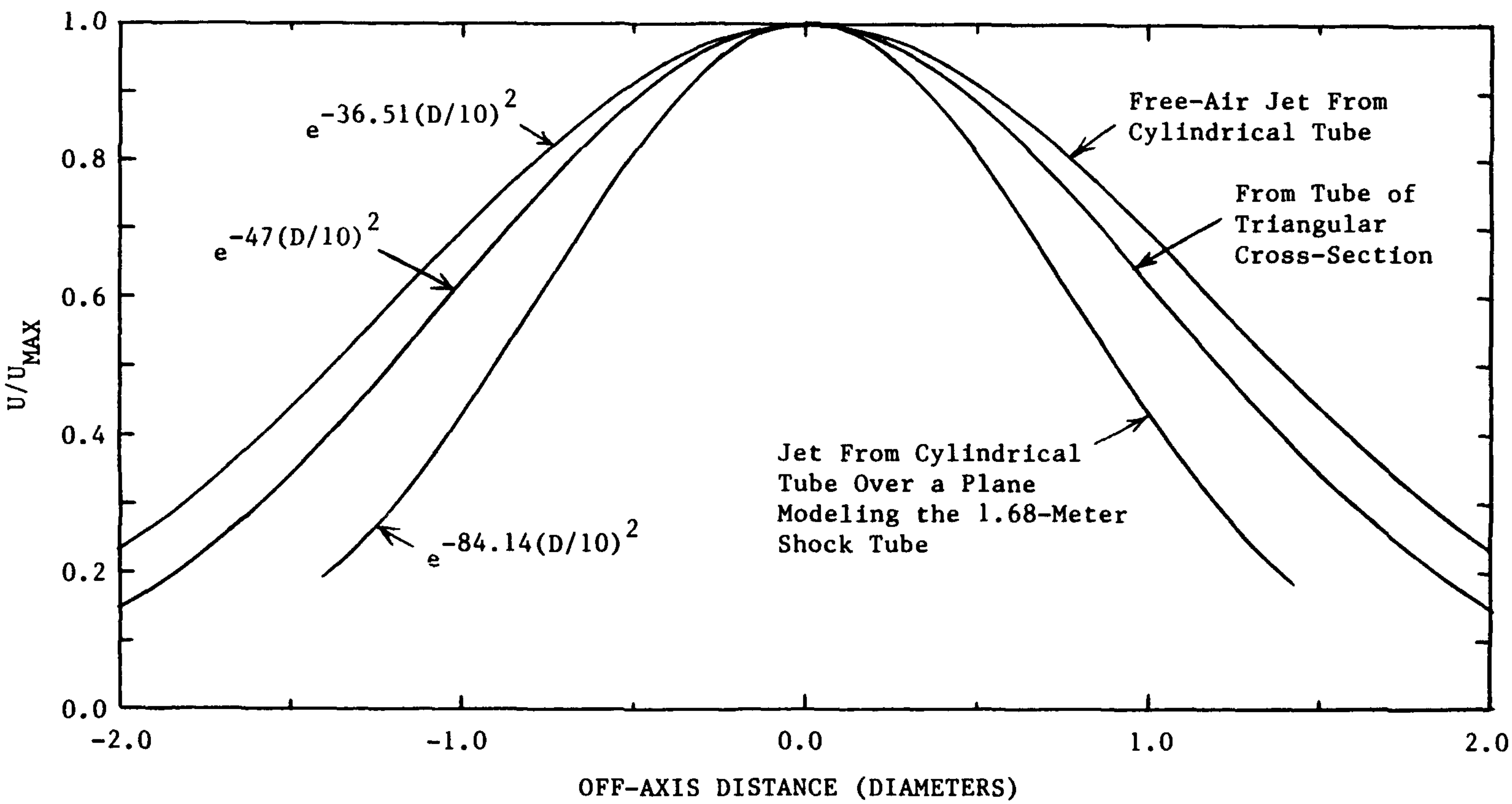

Figure 14. Comparison of the jet velocity profile at the height of the axis of the tube with the free-air jet profiles.

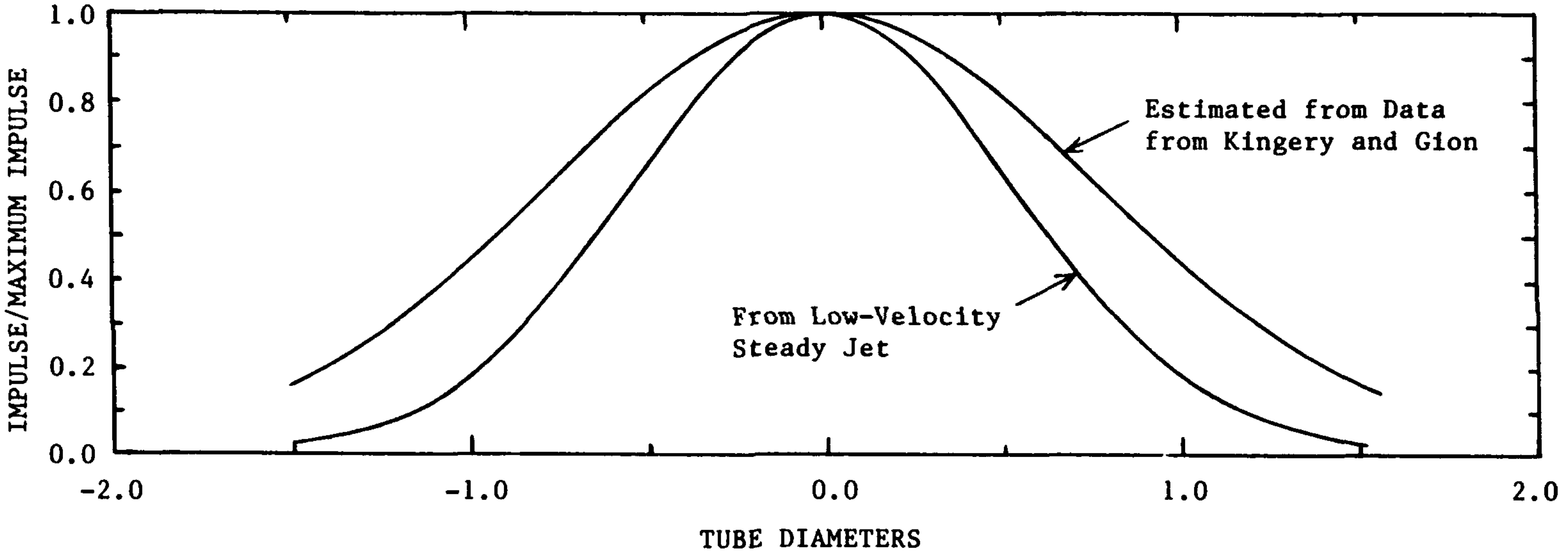

Figure 15. Comparison of the steady-flow jet impulse profile with that estimated from the data of Kingery and Gion.

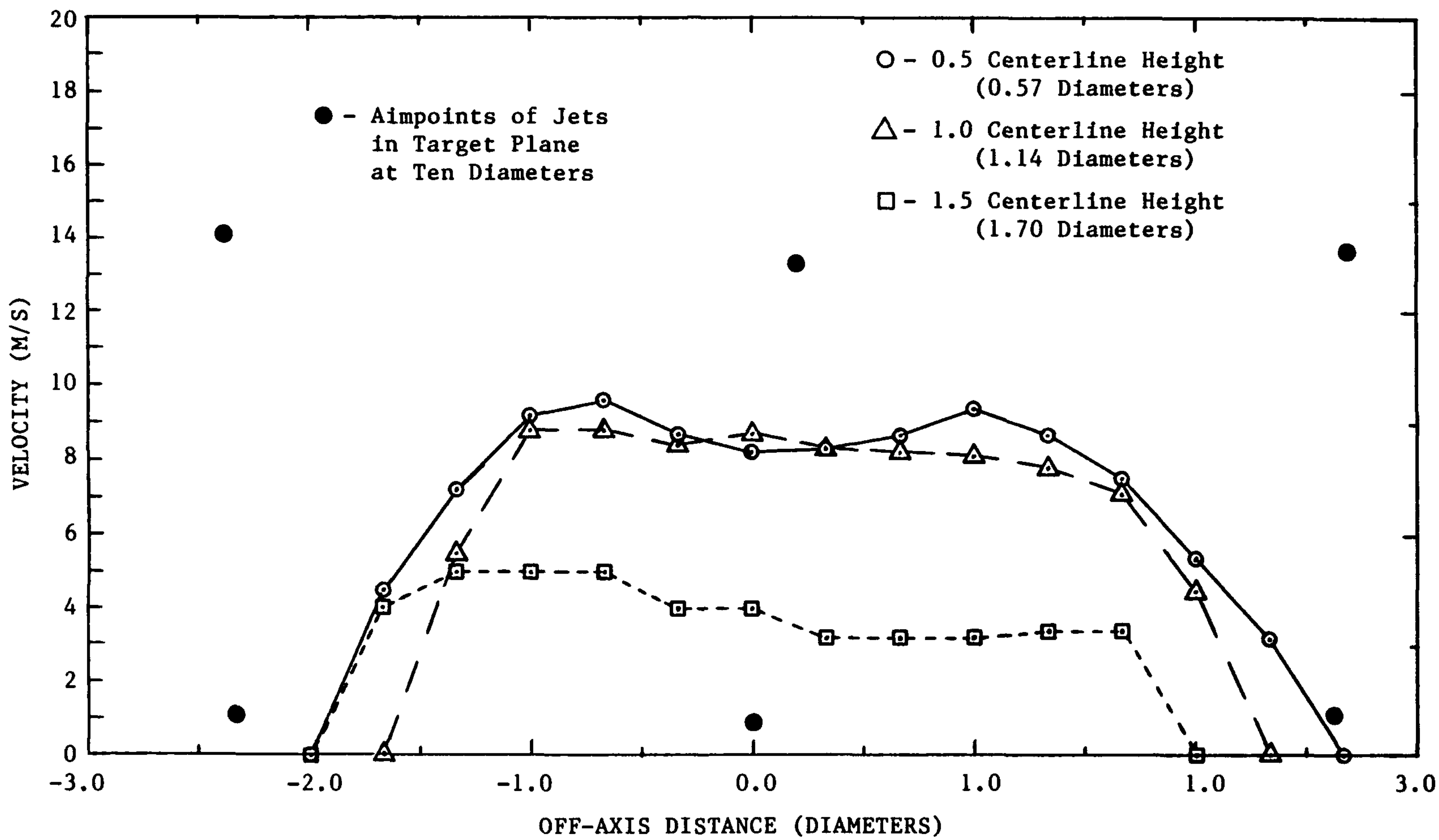

Figure 16. Measured velocity profiles at different heights produced by the six-jet configuration.

and the armored personnel carrier shown in Figure 2, but not wide enough for the truck. No flow was detected at a height of twice the centerline height.

D. Jet from the Ten-Jet Configuration.

Figure 17 shows the velocity measurements made at the two lowest heights for the ten-jet configuration shown in Figure 6. No flow was detected by the instrument at the upper two heights. The angles of the jet tubes were selected to produce aim points about 1.8 diameters apart in the target plane at ten diameters. However, the best arrangement had the two upper outer jet tubes moved in about one-third toward the adjacent jet tube, so that their aim points were about one diameter out from the aim point of the adjacent tube.

The profiles shown seem flat enough to be acceptable over a span of about 3.7 diameters. This might be adequate for the truck in Figure 2, which has a span of about 3.9 diameters.

E. Impulse Profiles.

As stated earlier, because of the constant density and steady flow the jet velocity profiles can be converted to dynamic pressure impulse profiles by squaring the ordinates. The values measured at the height of the axis of the cylindrical tube were normalized to the peak velocity value for the tube with the end open. These values were squared and plotted as shown in Figure 18.

The cost of broadening and flattening the jet is the drop in magnitude of impulse at ten diameters distance for the six-jet configuration to about 23 percent and for the ten-jet configuration to 15 percent of the peak magnitude for the open tube. The area under the six-jet profile is reduced to 54 percent of that under the curve for the open tube, and to 43 percent for the ten-jet configuration. Thus a major concern will be whether the spread jets will produce sufficient loading for overturning of targets of interest.

It is not known how well these results for the low-velocity steady-flow turbulent jet will apply for the jet from the 1.68 meter tube. Further studies of such fixtures should use a scaled model of the 1.68 meter tube.

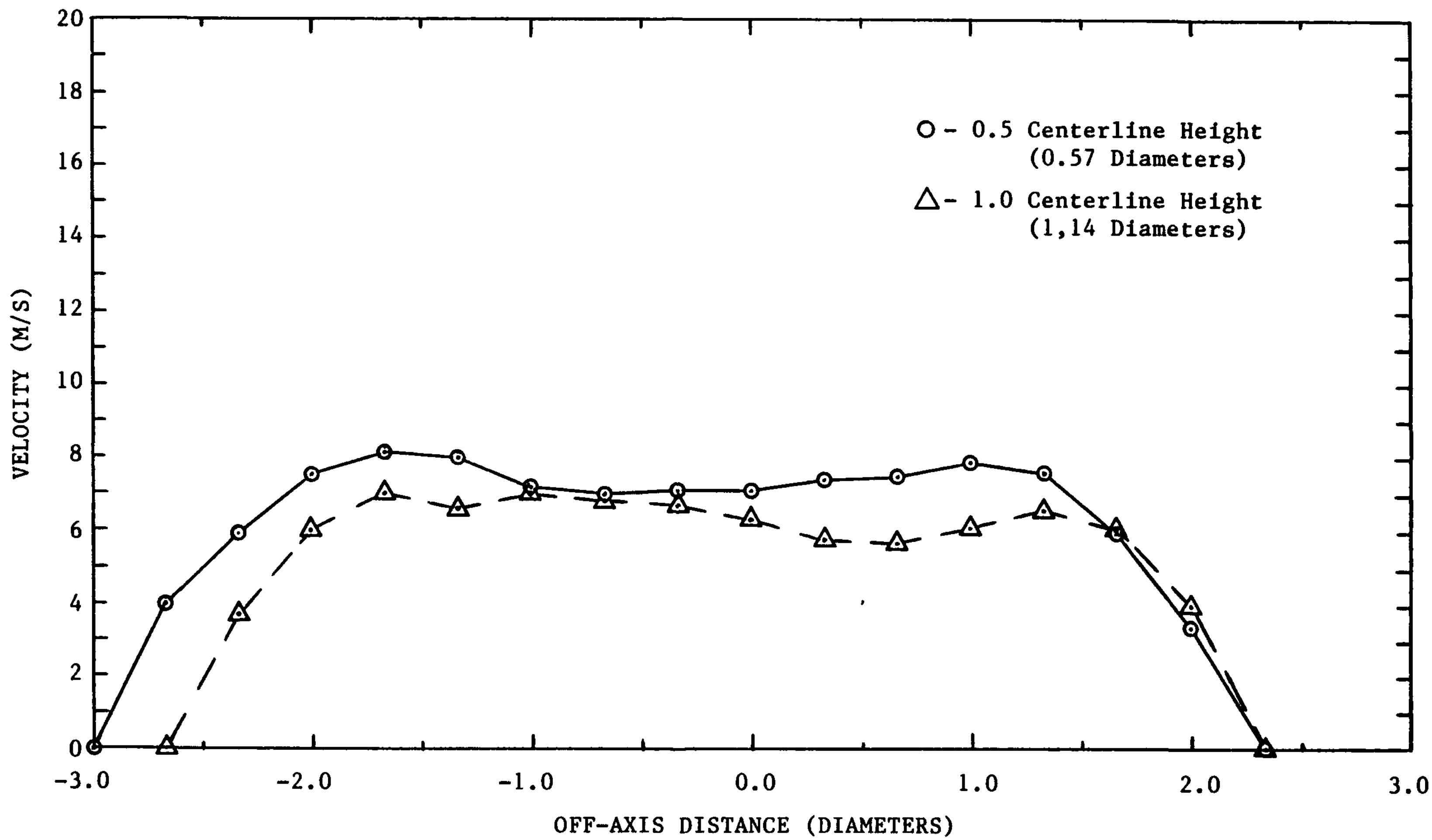

Figure 17. Measured velocity profiles at different heights produced by the ten-jet configuration.

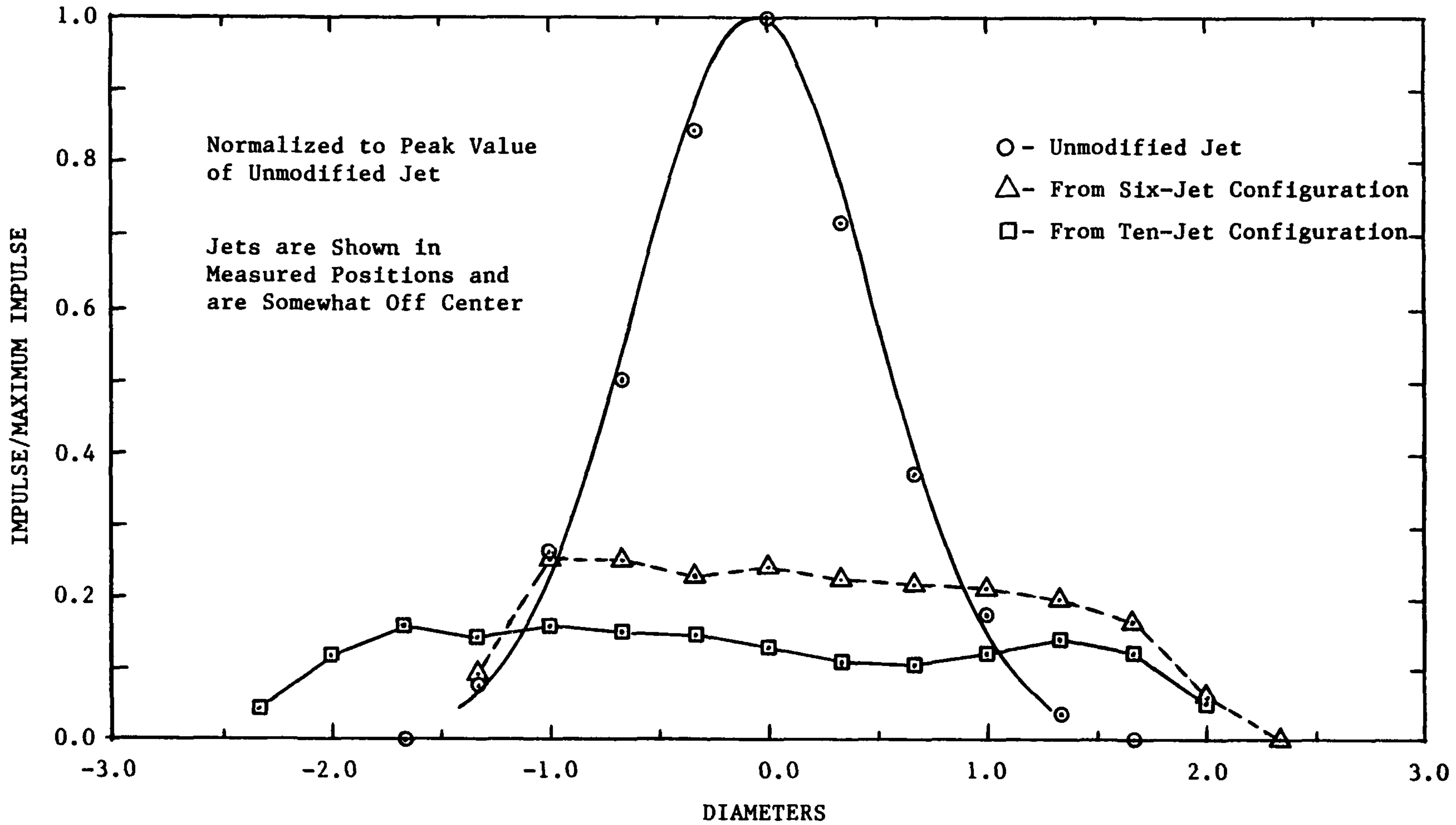

Figure 18. Estimated dynamic pressure impulse profiles for the open tube and for the six-jet and ten-jet configurations.

VI. CONCLUSIONS

The data available for estimating the characteristics of the jet exiting from the BRL 1.68 meter shock tube and the associated stagnation pressure impulse profile are very limited. Data from a 1/66 scale shock tube and from a 1/22 scale model tube producing a low-speed turbulent jet in steady flow were used to make an estimate of the impulse profile at a distance of ten diameters from the end of the 1.68-meter tube.

The estimated jet profile is narrow and would produce non-uniform loading over typical army targets such as a mobile electric power generator, a truck, and an armored personnel carrier.

The 1.68-meter tube has been used for overturning studies of a mobile electric power generator/trailer, and can be used for tests of outrigger designs. For simulation of blast waves, however, the jet dynamic pressure impulse profile needs to be increased in width to encompass the entire target and flattened to produce relatively uniform loading over the target.

The exploratory study using a low-velocity steady-flow turbulent jet showed that such a jet from a model shock tube configuration could be divided so that a larger span of approximately uniform flow velocity was produced at a range of ten diameters.

The effective width was expanded from about 0.7 diameters to 2.7 diameters by dividing the single jet into six directed jets, and to 3.7 diameters by dividing the single jet into ten directed jets.

The peak velocity at ten diameters was reduced by a factor of 2.1 for the six-jet division, and by a factor of 2.7 for the ten-jet division.

The magnitude of the dynamic pressure impulse per unit area was reduced to 23 percent of the peak magnitude for the open tube by the six-jet division, and to 15 percent by the ten-jet division. The total impulse of the six-jet profile was reduced to 54 percent of that of the open-tube profile. For the ten-jet profile the reduction was to 43 percent of that for the open-tube profile. It

is not known how well these results apply for the 1.68-meter tube, but the possibility of such reductions needs to be considered in choosing the jet modifications to be attempted.

Additional data are required to describe the characteristics of the jet outside the BRL 1.68 meter tube. Further experiments are required to determine the most appropriate fixture to broaden and flatten the jet stagnation pressure impulse profile.

The BRL 1.68-meter shock tube is a unique facility. The possibility of modifying it to serve as a non-ideal blast loading simulator should be pursued.

VII. DEVELOPMENT OF THE BRL 1.68-METER SHOCK TUBE AS A NON-IDEAL DRAG LOADING FACILITY - PROGRAM ELEMENTS

The plan proposed here consists of mapping the jets from the 1.68 meter tube, deciding on the modifications desired, developing a design of a fixture to produce the modifications, and building, installing and evaluating the fixture and the jets produced. These elements are discussed in more detail below.

A. Map the Jets Produced by the 1.68-Meter Shock Tube.

The proposed mapping is to be done at the target station, about ten diameters from the tube end. Four shots are to be fired, two at the upper pressure limit of 138 kPa (20 psi) with hot and cold drivers, and two at 34 kPa (5 psi) with hot and cold drivers. The instrumentation is to be stagnation pressure gages and a limited number of overpressure gages. The gages are to be placed in an array in the vertical plane perpendicular to the tube axis at ten diameters from the tube end. The narrowness of the jets shown in Figure 15 indicates that horizontal gage spacing should be not more that about 0.25 diameters near the tube axis. Data reduction equipment that can rapidly process the gage records and generate appropriate plots will be required for these tests and for tests that follow.

Measurements inside the tube should be included. As a minimum, a stagnation pressure and overpressure gage should be placed at the test station

inside the tube, and an overpressure gage near the tube end. Such measurements will be useful for comparison with records from a scaled model shock tube, and in evaluating the effects of adding a fixture on the end of the 1.68-meter tube on waveforms at the internal test station.

B. Determine the Modifications to the Jet that are Desired.

The capabilities of the unmodified jets to overturn targets will be estimated. For this purpose either the BLOM or TRUCK code or both should be modified to model the jet loading, and predictions made for selected targets. For example, it would be of interest to know whether a tank can be overturned.

If the jet loading available exceeds the overturning thresholds by a large margin, then losses produced by spreading the jet can be offset by increasing the shock pressure. The overturning thresholds, the extent that they can be exceeded, and the size of targets will be considered in selecting the modifications in the jets that are desired.

C. Build a Scaled Model Shock Tube.

The design of a suitable fixture must be developed experimentally, primarily by trial and error. Many tests will be needed, so that use of a scaled model shock tube for such tests is proposed. The 25.4 millimeter shock tube used by Kingery and Gion is not an exact scaled model and is too small for working with fixtures and for detailed mapping of the jet. For studying jet impulses it seems very important to have the dimensions of the driver and driven sections of the model shock tube of exactly the same proportions as in the 1.68-meter tube, and the tube axis at the same height in diameters above the ground plane.

A reasonable diameter for the model shock tube is 152 millimeters (six inches), a scale of 1/11. The lengths for the driver and driven sections would be 9.70 meters and 9.97 meters, respectively. Ten diameters from the end would be 1.52 meters. Jet mapping would require spacing some gages as close as 0.25 diameters, which would be 38 millimeters. Available stagnation pressure gages have a nose opening diameter of 5 millimeters, so a separation of 38 millimeters would be satisfactory.

Standard pipe and as few flanges as possible would be used in constructing the tube to minimize cost. It may be possible to install the tube so that the end extends over an existing concrete pad at the rear of the building containing the BRL 0.6-meter shock tube.

D. Map and Compare the Jets from the Model Tube with those from the 1.68-Meter Shock Tube.

An instrumentation array like that used to map the jets from the 1.68-meter tube is to be installed ten diameters from the end of the model tube. For this purpose it may be desirable to have the ten-diameter position at the edge of a concrete pad so that gage mounts can be placed in earth, with the gage probes projecting over the concrete surface. Stagnation and overpressure gages are to be installed inside the tube at positions corresponding to those at the test station and near the end of the 1.68-meter tube.

The model tube is to be fired first at conditions matching those used in mapping the jets from the 1.68-meter tube. The gage records are to be compared with those obtained from the large tube. The expectation is that the jets from the model will be sufficiently like those from the large tube that a fixture that works on the small model will work for the large tube.

E. Design, Build, and Attach Jet-Spreading Fixtures to the Model Tube.

The design process will consider the expanded width desired and the results reported here to estimate the number of jet-tubes required. The fixtures will be designed for maximum flexibility in pointing the jet-tubes while maintaining resistance to the high loads they must survive.

It is possible that the capability of spreading to two different widths will be desired. In this case, a fixture would be designed to allow the jet tubes of, for example, a six-jet configuration to be divided to form a twelve-jet configuration.

F. Measure and Evaluate the Jet Modifications Made by the Fixtures, and Adjust Fixtures for Optimum Performance.

Testing of the fixtures will involve firing at the upper and lower limits of the shock pressure range, evaluating the cnanges in the jet, adjusting the aim points of the jet tubes, and repeating the process. The testing will be continued until a satisfactory jet-tube configuration is found, or it is determined that a redesign is required to achieve the jet modifications desired.

G. Adapt the Best Fixture Design for the 1.68-Meter Shock Tube and Build and Install It.

The fixture found to be best in the model studies will be adapted for the 1.68-meter shock tube. It will be mounted so that it is not attached to the tube, and can be moved aside so that the tube is open. It will be subjected to enormous air loads, and designing it to stay in place under such loads and to be capable of being moved aside may be difficult.

Consideration should be given to designing the fixture so that attachments can be added at the end facing the tube to make the fixture function as a passive rarefaction wave eliminator.

H. Map the Jets Produced with the Fixture, and Adjust it for Optimum Performance.

The gage array used for measuring the jets from the model tube will be scaled to the dimensions appropriate for the large tube and installed. The performance of the fixture will be evaluated beginning with the lowest overpressure of interest. Then tests will be run at the highest pressure of interest for both cold and hot drivers. The aim points of the jet tubes will be adjusted to obtain optimum performance over the pressure range. It may be found that different settings will be required at the high end of the range than at the low end. Enough tests will be run to define the characteristics of the jets that can be produced with the fixture over the operating pressure range of the 1.68-meter tube.

I. Summarize the Results in a Users' Manual for the Facility.

This manual will describe the characteristics of the jets that can be produced over the pressure range and the corresponding settings of the jet-tubes.

It will contain recommendations for loading typical targets and waveforms to be expected.

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